

G10-FR4

Extracted from wikipedia:

“G-10 is a high-pressure fiberglass laminate. It is created by stacking multiple layers of glass cloth, soaking in epoxy resin, and compressing the resulting material under heat until the epoxy cures.

“FR-4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant. It contain 7-8 % Bromide as Tetrabrombisphenol A.”

The exact composition is manufacturer-dependent and likely not reproduceable, and we have in most cases been unable to find even a typical example.

The best we find is the specification list for materials used in the ALICE silicon strip detector (SDD) obtained from Flavio Tosello’s personal pages. The specification list is no longer available from that source, but probably exists in the ALICE documentation.

1. The glass fiber is E-Glass. The SSD pages give a detailed composition, but since many of the oxides appear only in trace amounts, we use the nearly-identical composition given in <https://www.azom.com/article.aspx?ArticleID=764> :

“E-Glass is a low alkali glass with a typical nominal composition of SiO₂ 54wt%, Al₂O₃ 14wt%, CaO+MgO 22wt%, B₂O₃ 10wt% and Na₂O+K₂O less then 2wt%. Some other materials may also be present at impurity levels.”

I actually used 22wt% CaO and ignored the small amount of MgO.

2. The epoxy binder is Epoxy resin Epotek 301-1:

Part A

Diglycidyl Ether of Bisphenol A

C₁₉H₂₀O₄

70% of Part A by weight

56% of Epotek 301-1 by weight

1,4-Butanediol Diglycidyl Ether

C₁₀H₁₈O₄

30% of Part A by weight

24% of Epotek 301-1 by weight

Part B

1,6-Hexanediamine 2,2,4-trimethyl-

C₉H₂₂N₂

20% of Epotek 301-1

3. Between 1986 and 2006 the Review of Particle Physics listed G10 as 60% SiO₂ and 40% epoxy, presumably by weight. The source of these numbers is unknown. They were adopted for the SDD materials list, and interpreted as wt% of E-Glass and Epotek 301-1. We have been unable to find any references to typical proportions of glass and epoxy, and so use this ratio here.

While our results for the E-Glass and Epotek 301-1 are consistent with the SDD numbers, our radiation length in G10 is 32.17 g/cm² rather than their 30.17 g/cm².